A new beamline for infrared microscopy in the SR center of Ritsumeikan University

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Abstract

A new beamline for an infrared (IR) microscpectroscopy is under construction in the SR center of Ritsumeikan University. We designed an optical system which collects synchrotron radiation (SR) photons by installing one toroidal mirror and two plane mirrors in the storage ring chamber. As a result, the acceptance angle can be widened up to 250 mrad in horizontal and 63 mrad in vertical. Our aim is to develop an IR microspectroscopy beamline with spatial resolution of the order of sub micron from mid-IR to far-IR. In this paper, we present a designed optical system of IR microspectroscopy and the results of ray-tracing.

1. Introduction

Infrared microspectroscopy (IRMS) is useful for studying local structures of organic materials and biomaterials because it enables us to observe where any specific molecules are distributed in a microscopic region. To accomplish an IRMS with high spatial resolution, we need a high intensity IR light enough to have high signal to noise ratio. Conventional IRMS sources are not sufficient, especially in the lower IR region. For example, spatial resolution of a commercially available instrument is several ten microns. Synchrotron radiation (SR) is a very promising candidate for the light source of IRMS. SR is highly brilliant and directional. In fact, IRMS beamlines have been constructed and used successfully in many SR facilities, such as NSLS[1], UVSOR[2], ALS[3], SPring-8[4], etc.

"AURORA" is a unique storage ring, consisting of one body superconducting magnet with a full circle electron orbit (1m diameter). Until now, research activities in the center have been focused in soft X-ray spectroscopies and micro-machine fabrication (LIGA). Since 'AURORA' is a soft X-ray ring, it cannot compete with large storage rings, such as SPring-8 in the higher photon energies. However, it is possible to surpass them in the IR and terahertz regions by collecting SR in a wider acceptance angle. Recently, we found to get the better performance than the other facilities by inserting mirrors in the storage ring chamber. Our aim is to develop an IRMS with a spatial resolution, as high as the order of sub-micron. In this paper, we report a designed optical system of IRMS from the SR ring to an FTIR and the results of ray-tracing for the first focal point in the optical system.

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2. Optical system

The designed optical system in the electron storage ring chamber is shown in Fig. 1. It is composed of one toroidal mirror and two plane mirrors. The toroidal mirror collects SR photons directly emitted from the electrons circulating the ring and two plane mirrors introduce the photons into the port from which an IR beamline is extended. In fact, there are several restrictions in installing any optical system inside the ring chamber which is not intended for IR use. The position and direction of the SR beam port are fixed. There are some devices inside the ring that block the reflected beam from the first toroidal mirror to the beam port (e.g. beam inflector, beam monitor). Setting two plane mirrors is due to these restrictions. The second plane mirror also functions to block the direct SR coming out from the port. The toroidal mirror has a width of 250 mm and a height of 45 mm. This system collects SR photons in the angular acceptance of 250 mrad in horizontal and 63 mrad in vertical. Since all the mirrors are installed in an ultra high vacuum storage ring chamber under a high magnetic field (3.8 T) and irradiated by direct SR (ca. 1 W/mrad), they should be water-cooled and fine-adjusted by using a remote-controlled non-magnetic, compact control system.

A designed optical system of the IR beamline is shown in Fig. 2. The IR beam is once focused inside the beam port and comes out from the storage ring body. An ellipsoidal mirror is installed at the front end of the beamline to focus the dispersed beam at the point just after a diamond filter (or BaF2 filter). According to the ray-trace simulation, an ellipsoidal mirror makes the beam size smaller than a toroidal mirror at the second focal point. After the filter, the IR beam passes through air and reformed in a parallel beam by a parabolic mirror and introduced into a commercial FTIR apparatus. Schwarzshild shrinkage optics will make the beam into several micron size. We also plan to insert a near-field optics to overcome the diffraction limit, aiming to spatial resolution of sub-micron order.

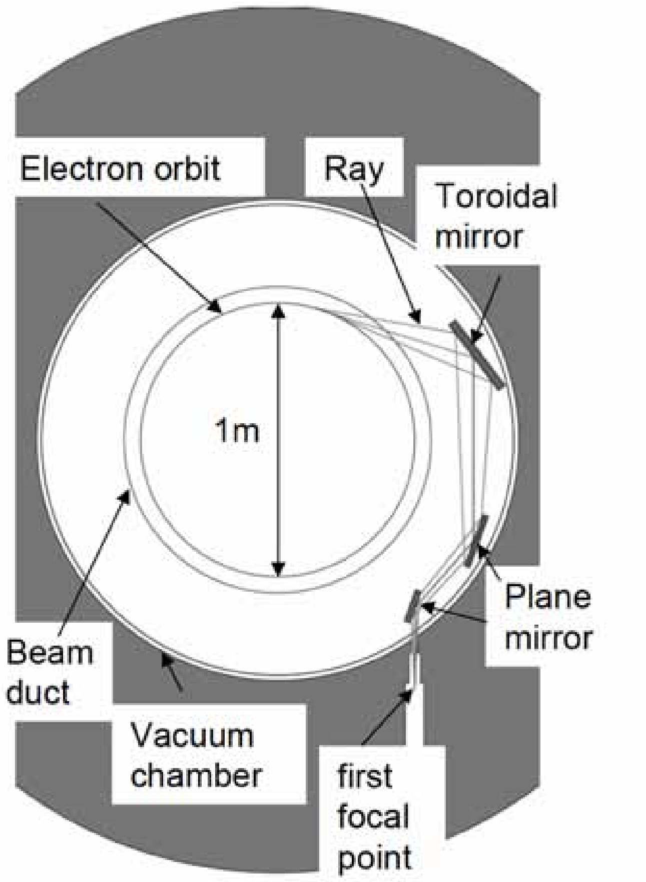

Figure 1 Schematic model of the designed optical system in the SR chamber.

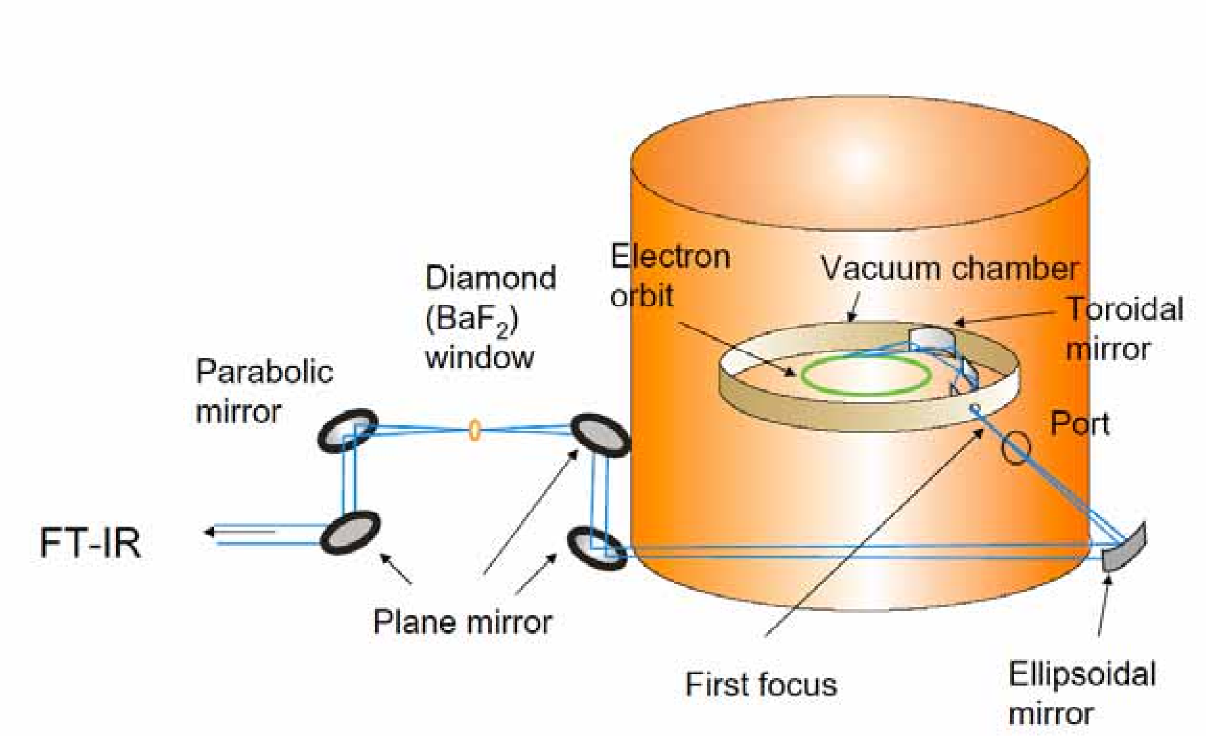

Figure 2 Schematic description of the designed optical system of the IR beamline.

3. 3. Ray-trace simulation

We simulated beam profiles at several focal points by using the 'SHADOW' ray-trace program [5] and determined the optimum optical system. Beam profiles depend on the electron beam profile, whose Gaussian σ is 1.3 mm in horizontal and 0.14 mm in vertical, as listed in Table 1. The toroidal mirror is located at 581 mm from the center of SR emission point and the first focal point is located at 1888.5 mm from the center of emission point. Figure 3(a) shows the beam profile at the photon energy of 0.1 eV (~1000 cm^{-1}), a typical value of mid-IR region, in which 's of the beam are 3.3 mm in horizontal and 0.40 mm in vertical, and the beam pattern is not point-like, but linear. Note that the beam profile is slightly shifted from the origin in horizontal. This might be due to a large horizontal acceptance angle (250 mrad). The calculated photon flux is of the order of 10^{14} (photons/sec/mrad (horizontal)/mA/eV). The emission angle of SR light, σ' is 73 mrad at a photon energy of 0.1 eV, which is fairly larger, in compared with that of IRSR in SPring-8 [6].

The ellipsoidal mirror is located at 2988.5 mm from the center of emission point and the second focal point is located at 3488.5 mm from the center of emission point. The beam profile of the second focal point at 0.1 eV is shown in Fig. 3(b). σ_h and σ_v are 1.3 and 0.19 mm, respectively. The beam size is smaller than at the first focal point and is comparable to that of the electron beam. Different from a low emittance ring, such as SPring-8, it is impossible to obtain a small spot at the focal point. However, the vertical size of the linear profile is sufficiently small and we expect a microscopic image by use of computer tomography.

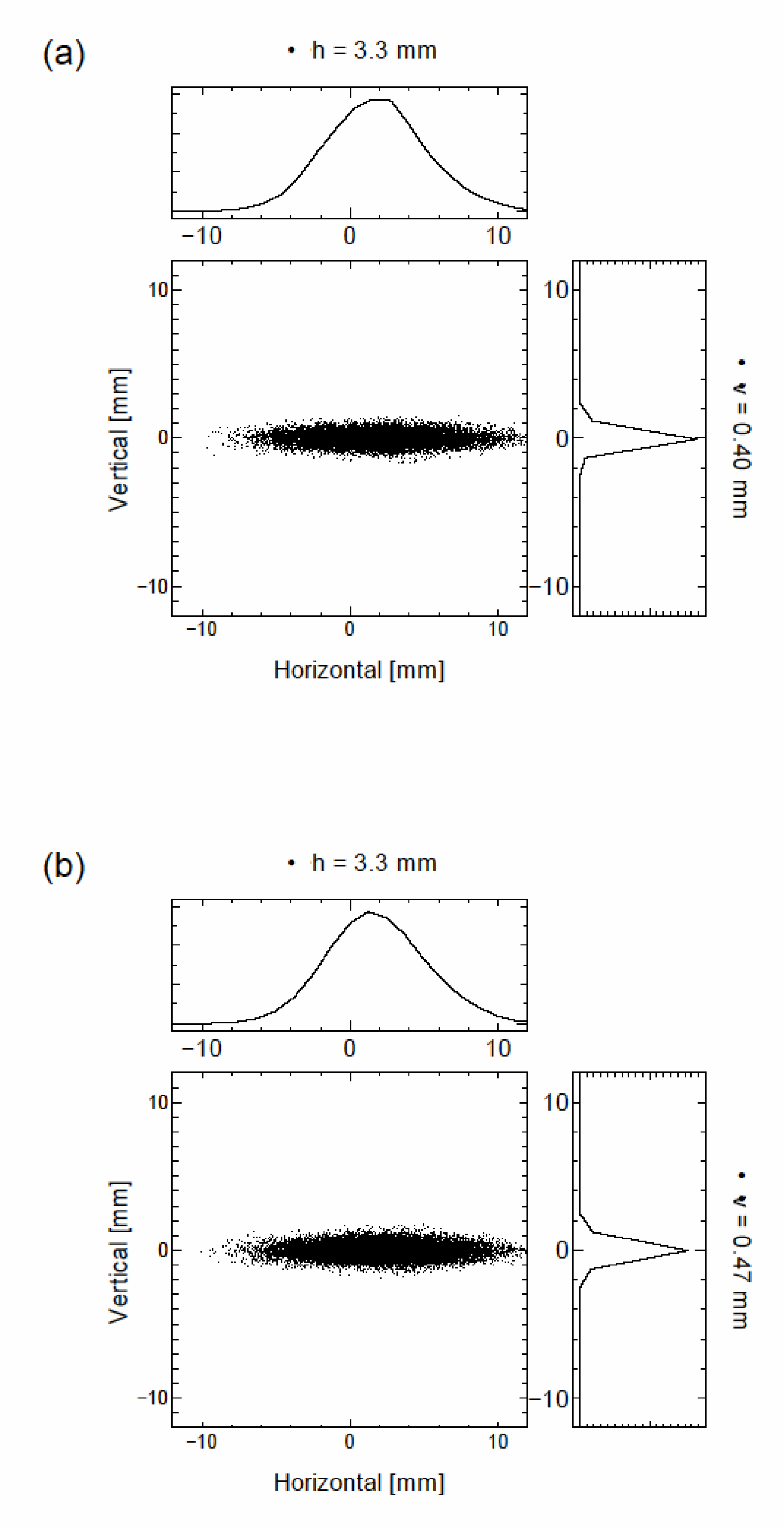

Figure 3 Ray-traced beam patterns in mid-IR region (at 0.1 eV) at first focal point (a) and at second focal point (b).

Similar features are obtained in the case of 0.01 eV (~100 cm^{-1}) which is in the far-IR region. Thus, we can expand the energy region from mid-IR to far-IR with a spatial resolution of sub-micron order through a Schwartzshild shrinkage optical system and near-field optics as-mentioned above.

4. Summary

We will construct an IR beamline in the SR center. An optical system was designed which collects synchrotron radiation (SR) photons with the acceptance angle of 250 mrad in horizontal and 63 mrad in vertical. One toroidal mirror and two plane mirrors are installed in the SR ring chamber. We expect that the IRMS beamline has a high intensity and high spatial resolution of the order of sub-micrometer.

Acknowledgements

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